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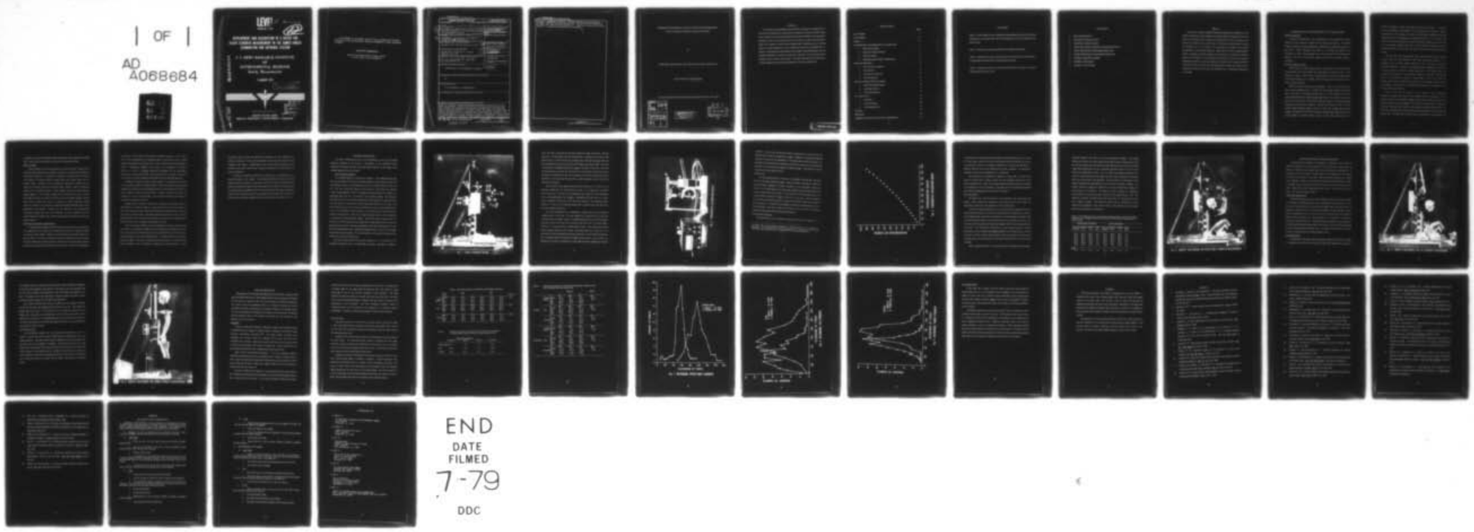

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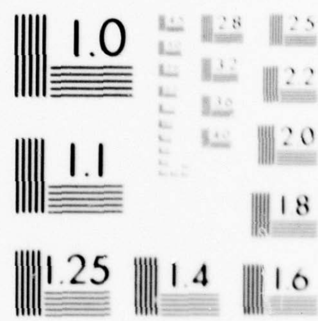

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DEVELOPMENT AND DESCRIPTION OF A DEVICE FOR STATIC STRENGTH MEASUREMENT IN THE ARMED FORCES EXAMINATION AND ENTRANCE STATION

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

9 JANUARY 1979

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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A device for muscular strength measurement designed for possible use in the AFEES is presented. Muscle groups involving the upper body, legs and trunk were selected for measurement as being most representative of the functional muscle groups most relevant to the Army's needs. The isometric (static) mode of testing was selected due to its simplicity of administration, reliability and reduced susceptibility to motivational influences. Biomechanical factors including subject-machine couplings, anatomical angles and minimization of synkinetic movement patterns are considered. The apparatus and calibration techniques are

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described. Standardized postures, anatomical angles and instructions are included. Reliability coefficients of 0.97, 0.92 and 0.83 were obtained for the upper body, legs and trunk respectively. Descriptive statistics and histograms for a representative population are included.

Development and Description of a Device for Static Strength Measurement

In the Armed Forces Examination and Entrance Station

by

Joseph Knapik, Dennis Kowal, Patrick Riley, James Wright, Michael Sacco

Project Reference: 3E762777A845

US Army Research Institute of Environmental Medicine, Natick, MA 01760

Foreword

A test battery was developed by this Institute in response to a Department of the Army (DA) requirement to determine the feasibility of physical fitness testing in the Armed Forces Entrance and Examination Stations (AFEES). This requirement stemmed in part from the high attrition rate occurring in basic training which a study at Ft. Jackson, SC found to be as high as 20%. Additionally, such a fitness battery is being considered for use in qualifying entrants for job assignments. In addition to psychological questionnaires and a physical work performance test, the originally developed test battery included the evaluation of the static (isometric) strength of three major muscle groups. This report describes the considerations, rational, equipment and procedures proposed for the static strength test.

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Abstract

A device for muscular strength measurement designed for possible use in the AFEES is presented. Muscle groups involving the upper body, legs and trunk were selected for measurement as being most representative of the functional muscle groups most relevant to the Army's needs. The isometric (static) mode of testing was selected due to its simplicity of administration, reliability and reduced susceptibility to motivational influences. Biomechanical factors including subject-machine couplings, anatomical angles and minimization of synkinetic movement patterns are considered. The apparatus and calibration techniques are described. Standardized postures, anatomical angles and instructions are included. Reliability coefficients of 0.97, 0.92 and 0.83 were obtained for the upper body, legs and trunk respectively. Descriptive statistics and histograms for a representative population are included.

CONSIDERATIONS IN THE DEVELOPMENT OF A STRENGTH TEST

AFEES Environment

A primary consideration in the development of the strength test for the AFEES was the limitations imposed by the testing environment. The AFEES situation requires the rapid processing of a large number of potential entrants on a daily basis. Often individuals with little or no training must perform this processing. In order to be applicable to this type of situation it was necessary to develop a test that could be given rapidly and would be relatively simple to administer.

Selection of Muscle Groups

The necessity for rapid testing made it impractical to test all the major muscle groups in the body despite their high degree of specificity (37). It was necessary to select a small sample of muscle groups that would be representative of total body strength and, if possible, include muscle groups that would be used in typical military situations.

Previous literature provided some guidelines. There was an indication that there may be "strength units" or a number of muscle groups related to functional parts of the body. For example, Borchart (2), in a cluster analysis of 27 muscle groups, identified five functional strength clusters which were specific to the arms, legs, trunk, neck and hip. Liba (25) also found some support for strength variables to group by functional body segments. Jackson and Frankiewicz (19) in a factor analytic study identified separate factors for static arm strength and static leg strength. Fleishman (12) found that a separate strength factor seemed to exist for trunk strength in his factor analytic study of various motor ability tests. In a

related investigation, Clarke (10) tested 25 major muscle groups. A "strength criterion" consisting of the average of all muscle groups was calculated. Multiple correlations with the strength criterion as the dependent variable and individual strength scores as the independent variable were performed. It was found that three or four muscle groups gave multiple correlations ranging from 0.94 to 0.98. The muscle groups included most often in these multiple correlations were the shoulder extensors, trunk extensors, hip flexors, knee extensors and ankle plantar flexors.

The selection of the muscle groups that would be representative of typical military tasks was made possible by MOS task descriptions provided by the proponent Army training schools through the Army Training and Doctrine Command (TRADOC). Analysis of these job descriptions suggested the upper body and legs as obvious choices for strength assessment. The TRADOC data also revealed that the ability to lift objects was required in many MOS. Poulsen (30), based on a biomechanical analysis of lifting ability, found a 0.76 correlation between trunk extensor strength and the capacity to lift weights from the floor to waist height. A pilot study in this laboratory demonstrated a correlation of 0.85 between these two parameters.

Thus, a review of the literature and an analysis of task requirements indicated that upper body, legs and trunk strength should be measured. For the legs and trunk the test originally designed by Hermansen, Eriksen and Larsen (17) for the Swedish Army was adopted. The leg test was essentially a "leg press" involving a combination of hip flexion, leg extension and ankle plantar flexion. The trunk test involved primarily trunk extension and was identical to the one used by Poulsen (30). The upper body strength test was developed in this laboratory and

combined arm flexion and shoulder extension using the major muscles of the upper torso. These tests are described in more detail in sections that follow.

Mode of Testing

Another problem involved the selection of a mode of testing. Strength can be measured either statically as an isometric contraction or dynamically as either an anisometric (concentric or eccentric) or isokinetic contraction (18). It may be more realistic to measure dynamic strength since many military tasks are of a dynamic nature. However, time and equipment requirements coupled with the factors of technique, motivation and safety make a dynamic mode of testing less practical for the AFEES situation. Static strength measures can be performed rapidly, appear to be minimally influenced by motivation (21), and if certain biomechanical factors are taken into account, they can be highly reliable. Further, many studies indicate that there is a moderate to high relationship among isometric, anisometric and isokinetic strength (1,6,20,28,35) although there is some disagreement (11,15,29,36). Studies from this laboratory have demonstrated correlations ranging from 0.65 to 0.93 between isometric, anisometric and low velocity isokinetic strength when the same muscle groups are measured in the same range of motion.

Biomechanical and Other Considerations

In constructing the apparatus and developing the procedures, it was necessary to be cognizant of the variables that complicate any attempt to measure strength in the intact human subject. Muscles act on skeletal levers to produce torque at an axis of rotation. This axis of rotation is the joint crossed by the active muscles. The force generated by internal muscular contraction can be measured externally as a force at a particular point distal to the active joint or joints. The coupling of

the subject to the machine thus becomes extremely important: more external force can be transmitted if the measuring device is positioned so that a longer skeletal lever applies the muscular force. In this case the mechanical advantage is greater. Additionally, changes in force output occur throughout the range of motion as a result of changing mechanical advantages and the physiological properties of the muscle (26,34,38). These factors make it necessary to standardize the subject-machine coupling and the angles of the involved body segments.

Synkinetic movement patterns, often referred to as associated movements (13) are another problem in strength testing. These are best seen under fatigued conditions (14), especially during sustained isometric contractions (31) but they are readily apparent during any maximal effort. Synkinetic patterns can reduce the reliability of a test by causing changes in the mechanical leverage and through the involvement of additional muscles.

Identification of synkinetic patterns for a particular test involves empirical observations on a number of subjects. Movements that occur and which appear to cause wide variances among trials must be identified and steps taken to avoid their reoccurance on future trials. It has been found helpful initially to retest the same group of subjects until the within-trial variance is reduced to an acceptable level. This level is set by the complexity and purpose of the task.

Once the synkinetic patterns have been identified a method of control should be selected. One method is through the use of mechanical immobilization devices (32). The placement of these devices must be standardized since they can have a marked influence on the value obtained (4,27). A simpler method, consisting of giving the subject a short set of verbal instructions just prior to testing, has also been successfully used for isometric contractions of short duration. These

instructions should include the particular movements to avoid, operations the subject can perform to avoid these movements (if any), and any reactive forces available to the subject. Unfortunately, since not all synkinetic patterns can be avoided by this latter method some mechanical stabilization is still necessary to optimize reliability.

A number of authors (5,7,22,23) have commented on the importance of the instructions given to the subject. Of particular significance seems to be the method whereby the subject is instructed to exert force. Kroemer and Howard (23) reported a difference of greater than 20% between two methods. They provided no recommendations but suggested that the instructions given the subject be reported. Chaffin (7) and Caldwell et al. (5) have proposed that the subject be instructed to build up to their maximal strength in about one sec and hold it for about four sec.

EQUIPMENT DESCRIPTION

The above considerations lead to the development of the static strength apparatus described in this section. A description of the calibration device, calibration techniques and some frictional effects inherent in the design of the strength apparatus are also included.

Static Strength Apparatus

The strength apparatus is illustrated in Figure 1. The supporting base plate (A) is constructed of 1/8 inch (0.32 cm) sheet aluminum reinforced with 3 inch (7.62 cm) aluminum channel. Its dimensions are 60 x 30 x 3 inches (152.40 x 76.20 x 7.62 cm). The main column (B) consists of two pieces of 3 inch (7.60 cm aluminum channel welded together to form a rectangle 76 inches (210.82 cm) in height. The supporting beams (C) are 1 1/4 inch (3.17 cm) aluminum tubing. The triangular beam (D) is built of 2 inch (5.08 cm) aluminum square tubing: the upper portion is 37 inches (99.06 cm) long and the lower portion 28 inches (71.12 cm) long. This entire beam pivots at E so it can be moved when not in use. The seat support (F) is a 20 x 30 inch (50.80 x 76.20 cm) piece of 1/8 inch (0.32 cm) sheet aluminum welded to five pieces of 1 inch (2.54 cm) aluminum pipe which in turn is welded to 2 inch (5.08 cm) square aluminum tubing. The seat (G) itself is formed from 1/8 inch (0.32 cm) sheet aluminum with angled braces supporting the back of the seat against the main column. The seat is upholstered with vinyl and padded with 1 inch (2.54 cm) polyurethane foam. Handholds (H) padded with 1/2 inch (1.27 cm) rubber are placed on the seat support. A seat belt passes on either side of the seat and is anchored to eye bolts (J) at the rear.

The force bar (K) used for the leg test consists of a 2 x 1 inch (5.08 x 2.54 cm) piece of aluminum that is 15 inches (38.10 cm) long. This piece is welded to

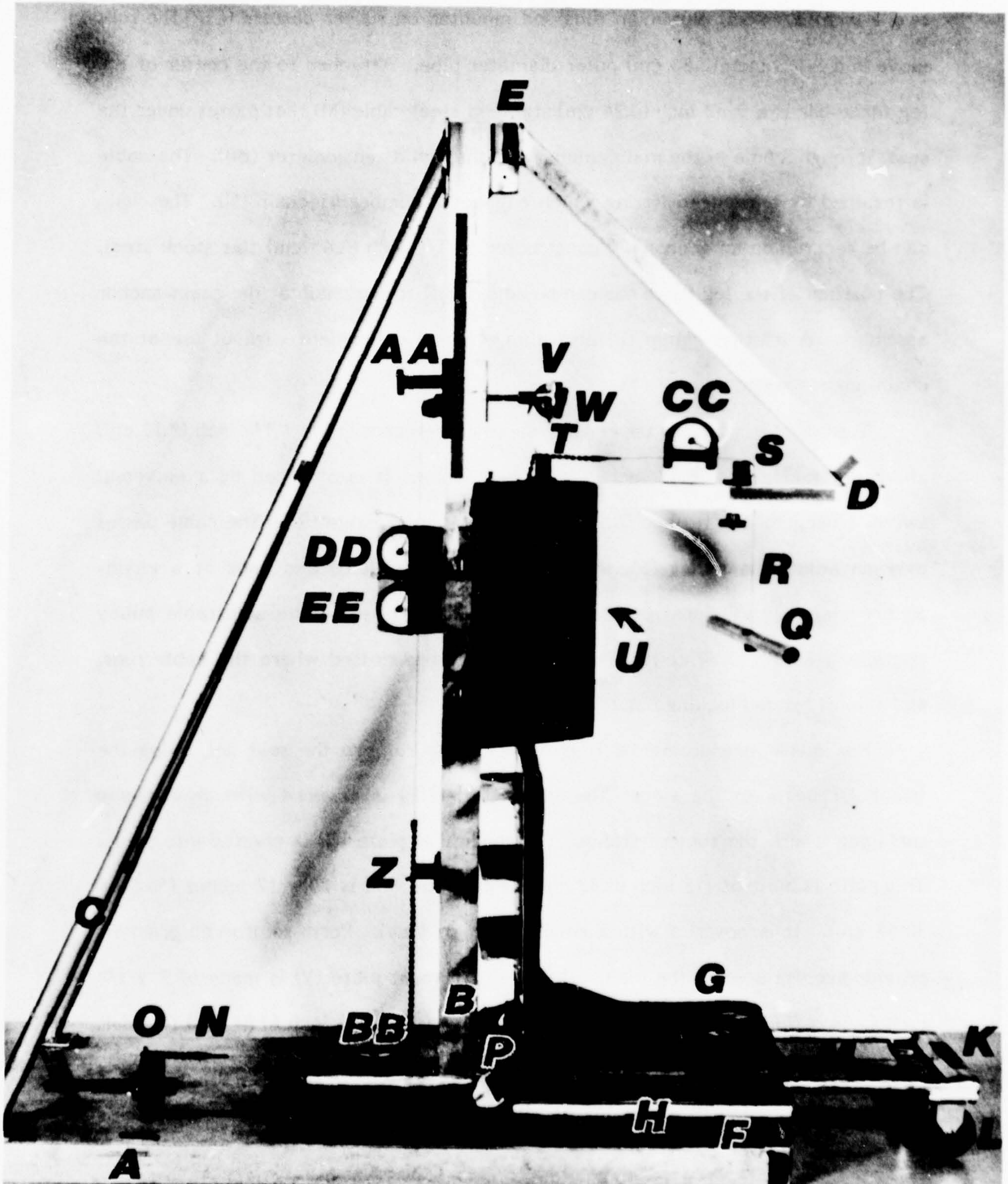

Fig. 1 STATIC STRENGTH DEVICE

two 1 inch (2.54 cm) aluminum rods and mounted on rubber casters (L). The rods move in a 1 1/8 inch (2.86 cm) outer diameter pipe. Attached to the center of the leg force bar is a 3/32 inch (0.24 cm) stainless steel cable (M) that passes under the seat, through a hole in the main column and through a tensiometer (BB). The cable is retained by a swedged fitting which engages a number 41 chain (N). The chain can be secured on an anchor (O) constructed of 1/4 inch (0.63 cm) flat stock steel. The position of the leg force bar can be adjusted with the chain at the chain-anchor assembly. A friction clamp (P) also allows initial adjustment without use of the chain-anchor assembly.

The force bar for the upper body measures (Q) consists of 1 1/4 inch (3.17 cm) aluminum tubing and is 18 inches (45.72 cm) long. It is attached by a universal swivel fitting to a 1/16 inch (0.16 cm) stainless steel cable (R). The cable passes over an adjustable pulley (S), through a tensiometer (CC) and ends at a chain-anchor assembly (T) identical to the one on the leg test. The adjustable pulley contains a 1 inch (2.54 cm) diameter wheel, that is slotted where the cable runs, and a knurl headed locking nut.

For trunk measurements, it is necessary to remove the seat and swing the triangular beam to the side. The seat support (F) is covered with an anti-slip surfacing where the subject stands. An abdominal plate (U) is pivoted into place. This plate is built of 1/8 inch (0.32 cm) sheet metal and is 20 x 12 inches (50.80 x 30.48 cm). It is covered with a double layer of vinyl. Form reinforced brackets provide support against the main column. The breast plate (V) is made of 2 x 1/4 inch (5.08 x 0.63 cm) aluminum flat stock braced by a 1/4 inch (0.63 cm) flat bar. It is 12 inches (30.48 cm) long with a slight concave curve. On one end it is attached to a strap (W) consisting of 2 inch (5.08 cm) nylon webbing and a buckle

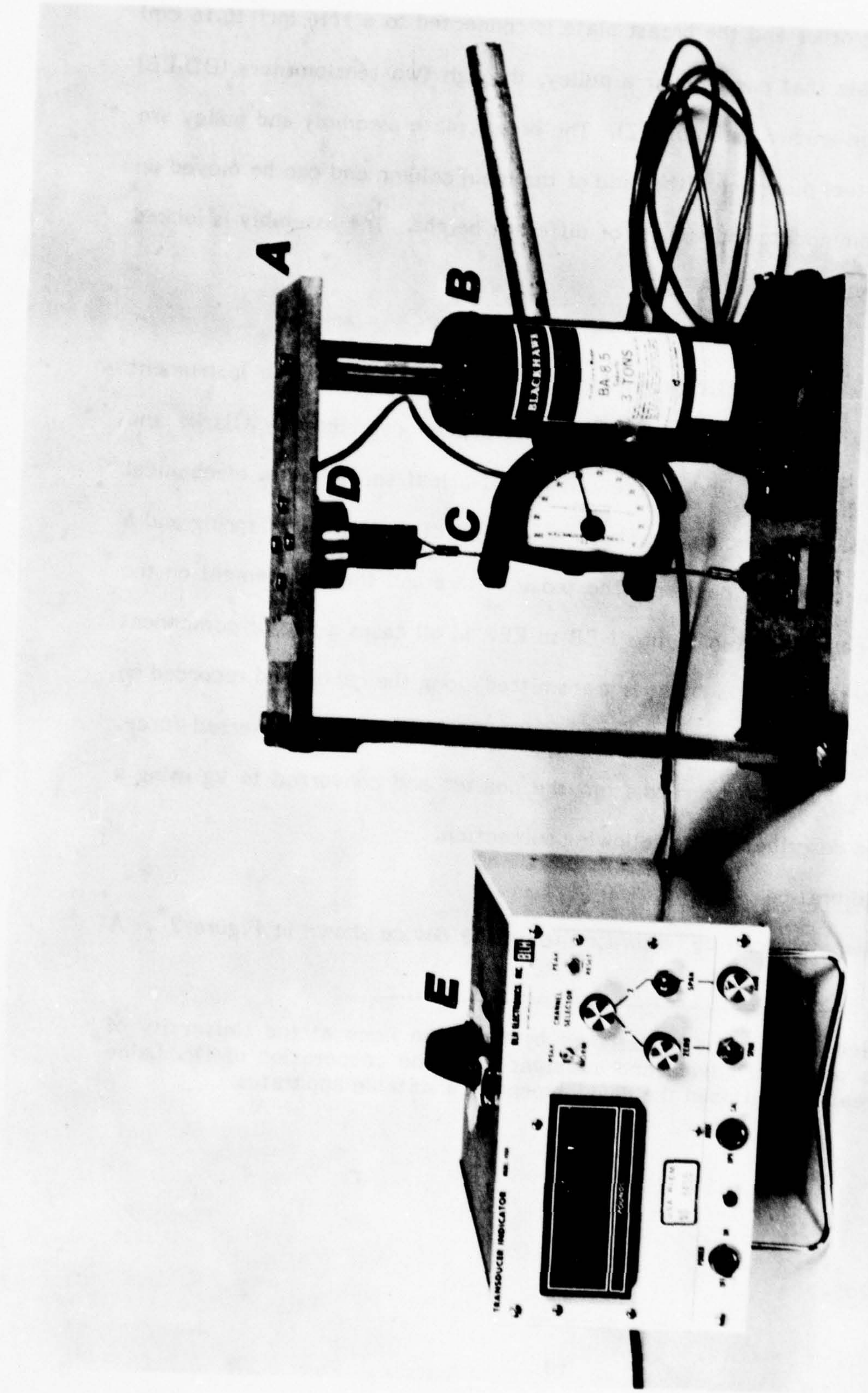

Fig. 2 TENSIOMETER CALIBRATION DEVICE

assembly. On the other end the breast plate is connected to a 1/16 inch (0.16 cm) stainless steel cable that passes over a pulley, through two tensiometers (DD,EE) and ends in a chain-anchor assembly (Z). The breast plate assembly and pulley are attached to two steel pieces on either end of the main column and can be moved up and down to accommodate individuals of different height. The assembly is locked in place with a knurl head nut (AA).

Tensiometers

The tensiometers (Pacific Scientific Co., Anaheim, CA) are the instrument used for recording muscular strength. They have been described by Clarke and associates (8,9). Basically, the device consists of a leaf spring and a mechanical pointer. Any tension exerted on a cable causes a deflection of the leaf spring and a resultant movement of the pointer. The tensiometers and their placement on the strength device can be seen in Figure 1 BB to EE. In all cases a vector component of the force exerted by the subject is transmitted along the cables and recorded on the tensiometers. A maximum force pointer remains at the peak exerted force. The tensiometer units can be read from the pointer and converted to kg using a calibration scale described in the following subsection.

Tensiometer Calibration

The tensiometers can be calibrated using the device shown in Figure 2*. A

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*A similar device was originally designed by Mr. John Bone at the University of Maryland. His technical advice and assistance and the cooperation of Dr. Laine Santa Maria greatly facilitated the development of a suitable apparatus.

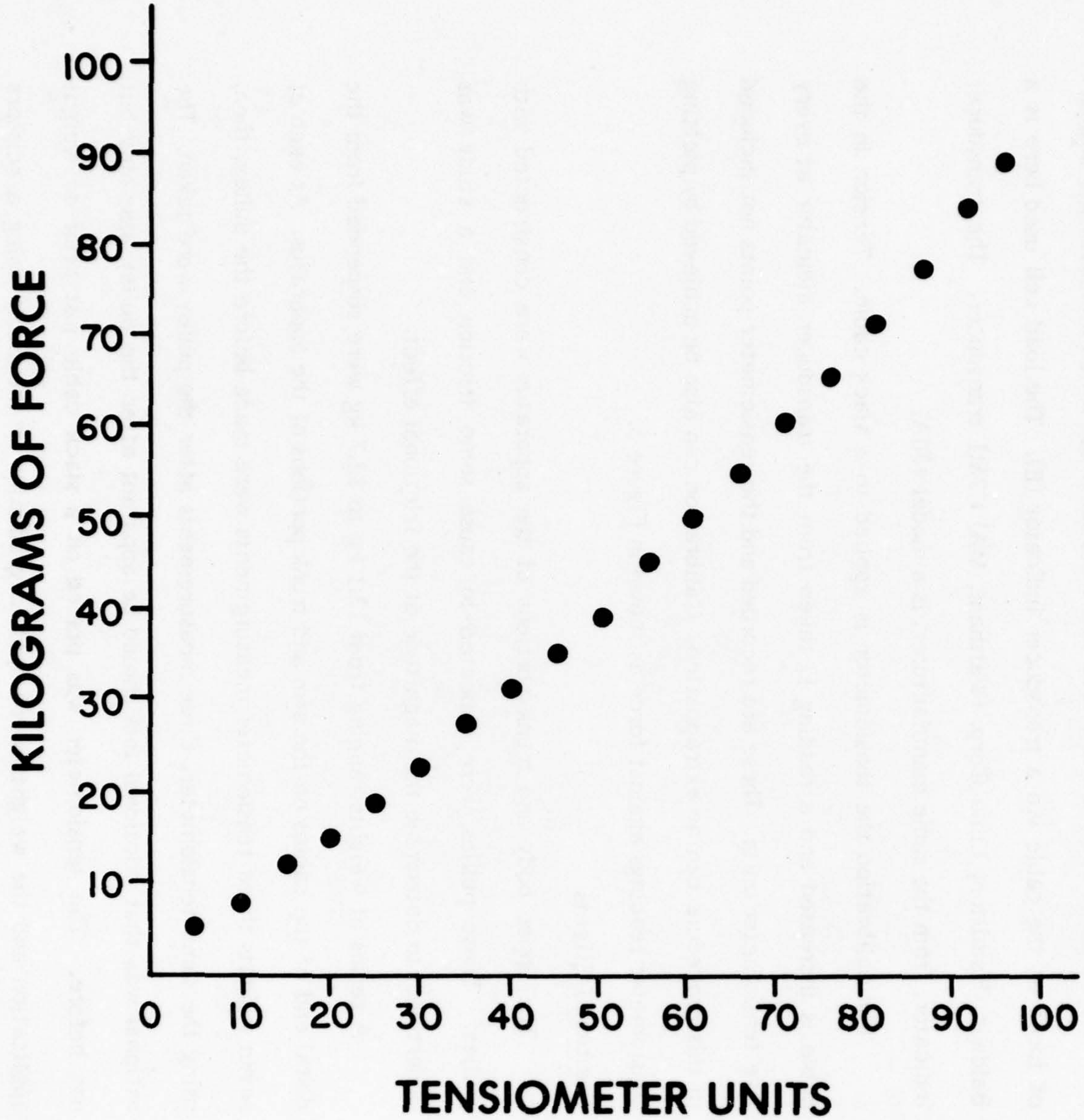

Fig. 3 TENSIOMETER CALIBRATION GRAPH

pivoted beam (A) is pushed upward by a hydraulic jack (B) placing tension in a cable (C). This cable is attached to a load cell transducer (D) which indicates the amount of force on the cable via a transducer indicator (E). The load cell used here is a Baldwin, Hamilton, Lima Corp. (Waltham, MA) C2M1 transducer. The transducer indicator, from the same manufacturer, is a model 450A.

For calibration the tensiometer is applied to a slack cable. Tension in the cable is increased and a reading is taken from the transducer indicator at every five tensiometer units. These are recorded and the tensiometer points not included in this procedure can be extrapolated. Calibration can also be achieved by plotting tensiometer readings against force as shown in Figure 3.

Frictional Effects

The upper body and trunk portions of the apparatus were constructed with pullies. These pullies were expected to cause some friction and a study was undertaken to determine the magnitude of the frictional effect.

A series of weights ranging from 13.1 kg to 82.7 kg were suspended from the distal end of the cables on the arm and trunk portions of the apparatus. At each of seven weights three tensiometer measurements were made before the pulley, then, using the same tensiometer, three measurements after the pulley were taken. The rational was that frictional loss should be apparant after the pulley assembly but not before. The tensiometer was placed on a slack cable just prior to weight application and the weights were applied gradually to the cable using a scissors type jack. In order to obtain these measures on the trunk portion of the device the triangular beam was removed, the device tilted forward 90° and the trunk cable extended.

Table 1 depicts the results. The values shown for the before and after pulley

measures represent the mean of the three tensiometer readings. The average differences between the actual weight and the before pulley readings were 0.33 kg for the trunk portion and 0.05 kg for the upper body portion over the entire weight range. These differences were not statistically significant ($t(6)=1.33$ for trunk and $t(6)=0.15$ for upper body, $p > .05$). Two way ANOVA for repeated measures on one factor (3) were performed on the before and after pulley measures for the upper body and trunk portions of the apparatus. The main effect was the before vs after pulley readings and the repeated factor was the three tensiometer readings. This analysis showed no significant differences among the tensiometer readings for either portion of the device. The before vs after readings were significant ($F(1,19)=26.52$ for the trunk and $F(1,19)=26.47$ for the upper body, $p < .05$). This difference amounted to 3.9% for the trunk and 4.1% for the upper body over the entire range of weights. The interaction effect was not significant on either portion of the apparatus. Thus, there is about a 4% frictional loss on the upper body and trunk portion of the apparatus.

Table 1. Actual Weight and the Tensiometer Readings Before and After the Pulley Assemblies for the Upper Body and Trunk Portions of the Static Strength Device (Values in kg).

UPPER BODY PORTION				TRUNK PORTION			
ACTUAL WEIGHT	BEFORE (B)	AFTER (A)	DIFF (B-A)	ACTUAL WEIGHT	BEFORE (B)	AFTER (A)	DIFF (B-A)
82.6	82.4	81.5	0.9	82.7	82.0	82.1	-0.1
71.0	69.3	69.2	0.1	71.1	71.0	69.3	1.7
59.5	60.3	56.3	4.0	59.5	59.7	58.8	0.9
48.0	48.7	45.2	3.5	48.0	48.4	45.2	3.2
36.4	35.3	34.0	1.3	36.4	37.8	35.2	2.6
24.8	25.0	23.0	2.0	24.7	25.1	23.0	2.1
13.1	14.0	12.0	2.0	13.2	13.9	11.0	2.9
Mean:							
47.9	47.9	45.9	2.0	47.9	48.3	46.4	1.9

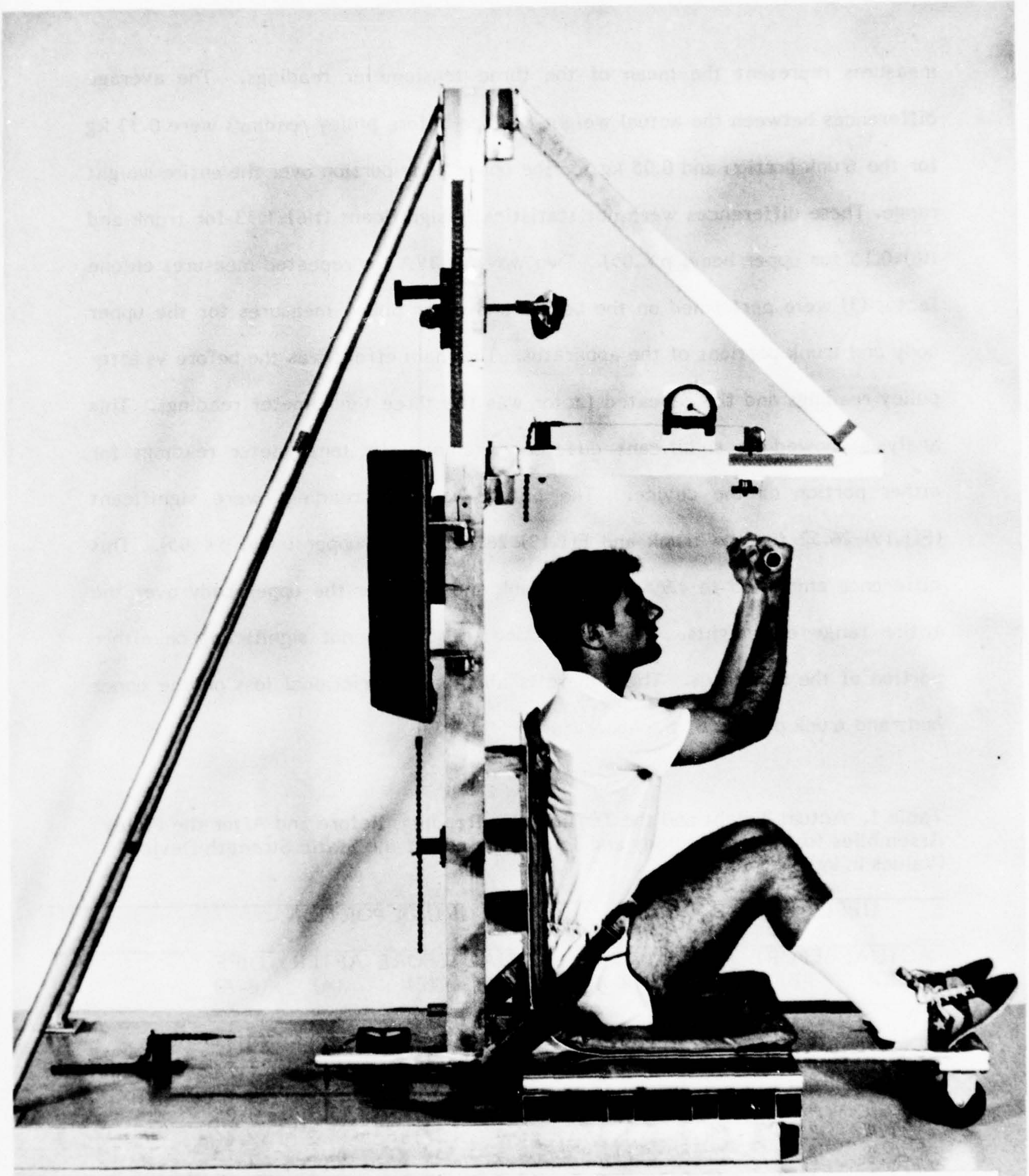

Fig. 4 SUBJECT POSITIONING FOR UPPER BODY STRENGTH MEASUREMENT

POSTURE AND SUBJECT-MACHINE COUPLING

The positioning and posture of the subject is important in the control of synkinetic patterns and in the achievement of maximal force output since the latter is a function of body support and reactive forces that are available (4). A description of how the subject was positioned in the apparatus and the general instructions are included in this section. Specific testing instructions are included in the Appendix. Subjects were instructed to build to maximal strength as rapidly as possible without jerking and to maintain that level of exertion until told to relax. Subjects were told to relax after about three to five sec. after their force output was relatively constant (22,23).

Upper Body Measurements

The subject's posture for upper body strength measurement is shown in Figure 4. The subject was asked to sit as far back as possible in the chair with the arch of his foot on the leg force bar. The seat belt was placed tightly around his waist. He grasped the upper body force bar such that his hands were about shoulder distance apart and equidistant from the center of the bar. The pulley and chain assemblies (Figure 1S,T) were adjusted such that the upper arm was parallel to the floor and the angle at the elbow was 90°. The elbow angle was obtained using a goniometer and the anatomical landmarks provided by the acromion process, lateral epicondyle and ulnar styloid process of the right arm. The subject was instructed to pull down as hard as possible on the bar without flexing his trunk.

Leg Measurements

The position of the subject for leg strength measurement is shown in Figure 5. The position was similar to that used for upper body measurement except that

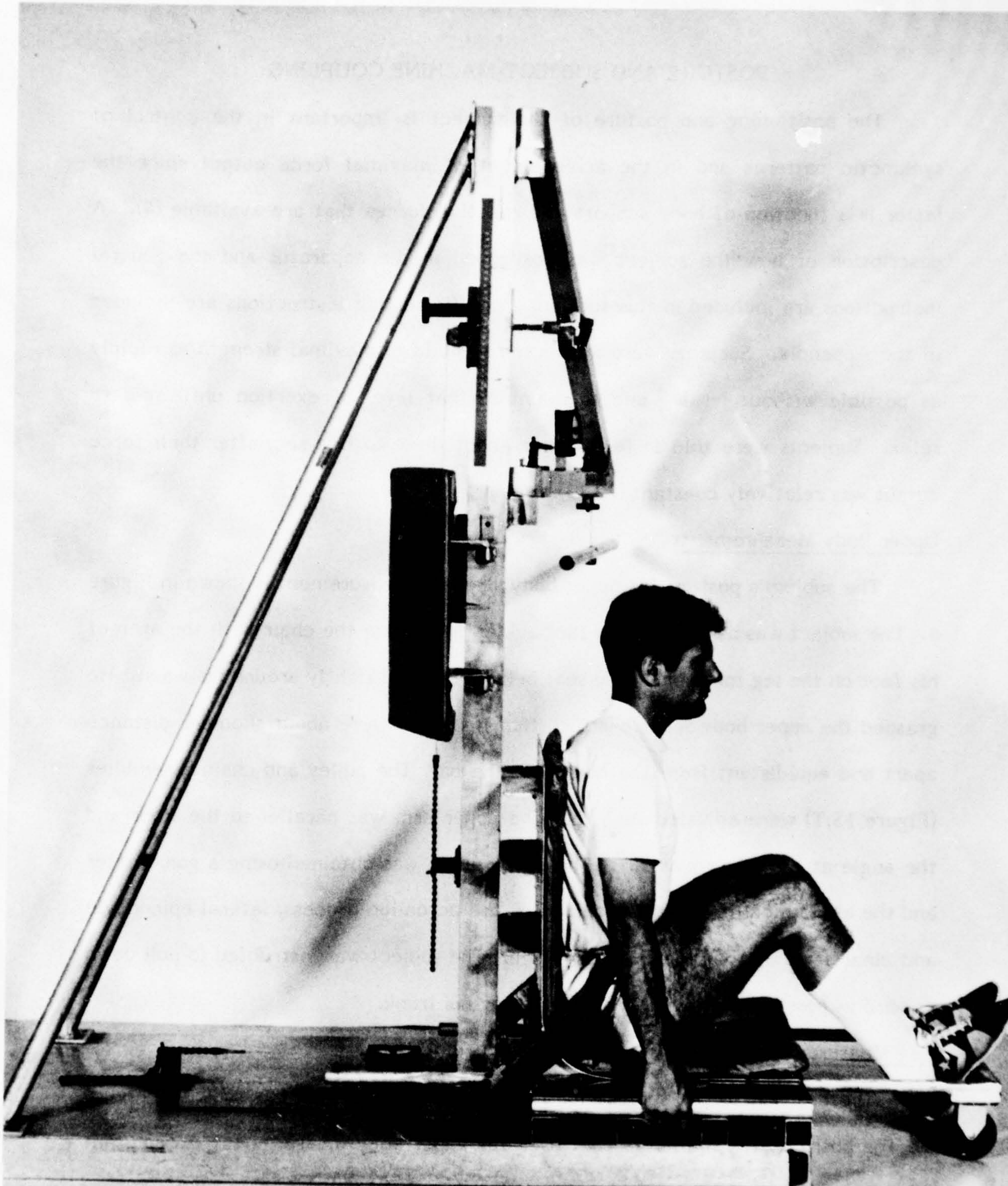

Fig. 5 SUBJECT POSITIONING FOR LEG STRENGTH MEASUREMENT

the triangular beam was swung away and the subject asked to grasp the handholds on the side of the apparatus. The position of the leg force bar was adjusted using the chain anchor (Figure 1N,O) assembly so that a 90^{o} angle was obtained at the knee. This angle was set with a goniometer using the greater trochanter, lateral condyle and lateral malleolus of the right leg as landmarks.

Pilot studies indicated that there was a tendency for the subject to elevate his body off the seat when applying maximal force to the bar. This altered the preset angle of the knee. To circumvent this, the subject was informed of the problem and instructed to pull himself down onto the seat at the same time he pushed out on the force bar. Handholds padded with 1/2 inch rubber were placed on the side of the apparatus to facilitate the subjects assistance. He was additionally instructed not to flex his trunk.

Trunk Measurements

The standardized position for trunk extension measurements is shown in Figure 6. The seat was removed and the abdominal plate placed against the main supporting beam. The subject stood facing the apparatus with his feet against the toe piece and as close together as possible. The breast plate and nylon strap (Figure 1W,V) were placed around the arms and back with the top of the strap three inches inferior to the acromion process. Subjects were instructed to pull back as hard as possible on the strap while pushing forward with their hips on the abdominal pad. Hands were kept on the thighs, and the subject instructed not to bend his knees.

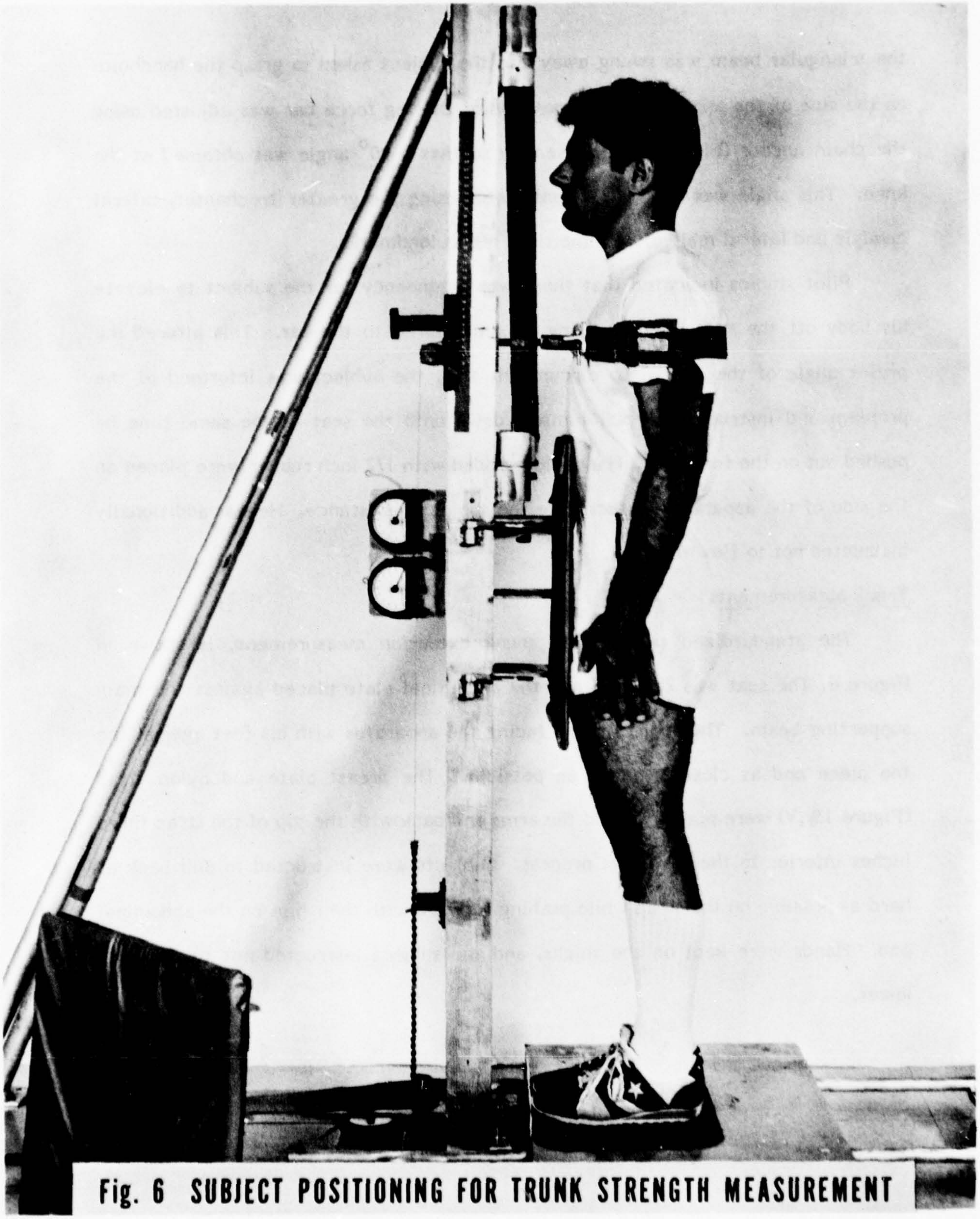

Fig. 6 SUBJECT POSITIONING FOR TRUNK STRENGTH MEASUREMENT

FORT JACKSON STUDY

The apparatus and techniques described above were tested on a sample of 948 male and 496 female recruits. These subjects were in basic training at Ft. Jackson, SC from January to March of 1978. The actual testing was performed during their first week so they had undergone little or no physical training and may be considered somewhat representative of a sample of subjects in an AFEES station. This section describes the reliability of the device and measurement techniques, provides normative data on the sample and discusses the time required to test subjects and train technicians.

Reliability

In order to determine reliability a subsample of eight males and eight females was obtained from the larger Ft. Jackson sample. Reliability was estimated using intraclass correlational techniques (33). The among subjects variations were considered true variance while the variations due to days and trials were considered error variance. Subjects were given three trials on each muscle group on the first day and three more trials on a second day. Thirty seconds rest was given between trials and 24 hours elapsed between days one and two.

Table 2 shows the descriptive statistics. A one way repeated measures ANOVA (3) was performed on the six available trials. As shown in Table 2 none of the F-values were statistically significant indicating the scores remained the same across trials and over days. There was a slight tendency for the trunk values to increase from day one to day two.

In order to estimate the reliability a two way nested ANOVA was performed (33). Table 3 shows the results of this analysis in terms of the percentage variance due to subjects, days and trials. In all cases the largest variance was among

subjects while the error over days was larger than the trials error. Reliability was acceptably high for the upper body and legs but the trunk showed a large percentage of day to day variance resulting in lower reliability. The slight tendency for the force values to increase from day one to day two on the trunk may be the result of familiarization. Subjects were also noted to comment on the unfamiliarity of the movement. The lower reliability mandates caution in interpreting data from this portion of the apparatus in its present stage of development. Attempts to improve the reliability of the trunk are on-going.

Normative Data

Descriptive statistics for the entire Ft. Jackson sample is presented in Table 4. The column labeled "mean" consists of the mean of all available trials. Thus, if only two trials were available on a subject the average of these two trials made up that individuals mean score.

Laubach (24) reviewed several articles on the comparative muscle strength of men and women. In summarizing these studies he reported that the upper extremity strength of females was 55.8% that of males, lower extremity strength 71.9% of men and trunk strength, 63.8% that of men. In the present study these figures were 56.5%, 64.2% and 66.0%, respectively.

Histograms showing the distribution of scores for males and females on the three muscle groups appear in Figures 7 through 9. Similar histograms were presented by Hermansen (16) for a sample of male Norwegian conscripts. The range of motion used in both Hermansen's and the present study was identical making comparison with the males in this study possible. For both the legs and trunk the Norwegian conscripts showed higher values than their American counterparts. The leg values were also more variable for the American sample.

Table 2. Descriptive Statistics and ANOVA for Reliability Estimation

	DAY	ONE			TWO			
	TRIAL	1	2	3	1	2	3	F-VALUE
UPPER BODY	MEAN	77.7	76.7	75.9	76.9	76.8	76.3	0.34
	SD	15.9	15.9	16.2	16.9	17.3	15.8	
	MAX	102.0	97.0	98.0	108.0	103.0	99.0	
	MIN	52.0	54.0	51.0	48.0	45.0	48.0	
LEG	MEAN	151.1	152.6	149.4	150.9	147.3	151.8	0.15
	SD	53.8	57.7	54.8	51.5	52.2	62.4	
	MAX	284.0	290.0	273.0	268.0	255.0	307.0	
	MIN	67.0	67.0	67.0	69.0	69.0	67.0	
TRUNK	MEAN	59.6	59.3	60.9	60.4	62.4	62.1	0.65
	SD	11.2	14.1	11.6	12.0	12.8	13.5	
	MAX	81.0	85.0	82.0	82.0	80.0	80.0	
	MIN	41.0	34.0	45.0	33.0	36.0	33.0	

Table 3. Reliability Estimates and Portions of Total Variance Attributable *to Among Subject, Between Days and Among Trials Variance*

	PERCENT VARIANCE			
	SUBJECTS	DAYS	TRIALS	R-VALUE
UPPER BODY	91.1	5.1	3.8	0.97
LEG	82.6	13.8	3.6	0.92
TRUNK	64.4	26.1	9.4	0.83

Table 4. Descriptive Statistics for Male and Female Basic Trainees on the Static Strength Device (Values in kg)

			TRIALS 1	TRIALS 2	TRIALS 3	MEAN
MALES	UPPER BODY	N	924	920	916	924
		MEAN	96.8	97.1	98.2	97.2
		SD	19.4	18.7	18.6	18.7
		MAX	169.0	155.0	166.0	
		MIN	49.0	47.0	49.0	
	LEG	N	947	947	947	947
		MEAN	145.1	142.0	141.2	142.5
		SD	38.7	38.1	37.9	37.8
		MAX	301.0	287.0	301.0	
		MIN	48.0	47.0	47.0	
	TRUNK	N	934	934	933	934
		MEAN	73.2	72.1	72.7	72.3
		SD	19.8	19.1	18.8	18.7
		MAX	177.0	164.0	169.0	
		MIN	16.0	17.0	16.0	
FEMALES	UPPER BODY	N	488	488	488	488
		MEAN	54.5	55.4	55.7	54.9
		SD	11.3	11.5	11.4	11.2
		MAX	109.0	118.0	109.0	
		MIN	10.0	10.0	11.0	
	LEG	N	494	494	493	494
		MEAN	92.5	91.5	90.8	91.4
		SD	28.8	29.7	30.1	29.3
		MAX	193.0	238.0	209.0	
		MIN	40.0	38.0	39.0	
	TRUNK	N	496	496	495	496
		MEAN	47.7	47.8	48.3	47.7
		SD	14.0	13.7	13.6	13.4
		MAX	111.0	111.0	100.0	
		MIN	8.0	8.0	9.0	

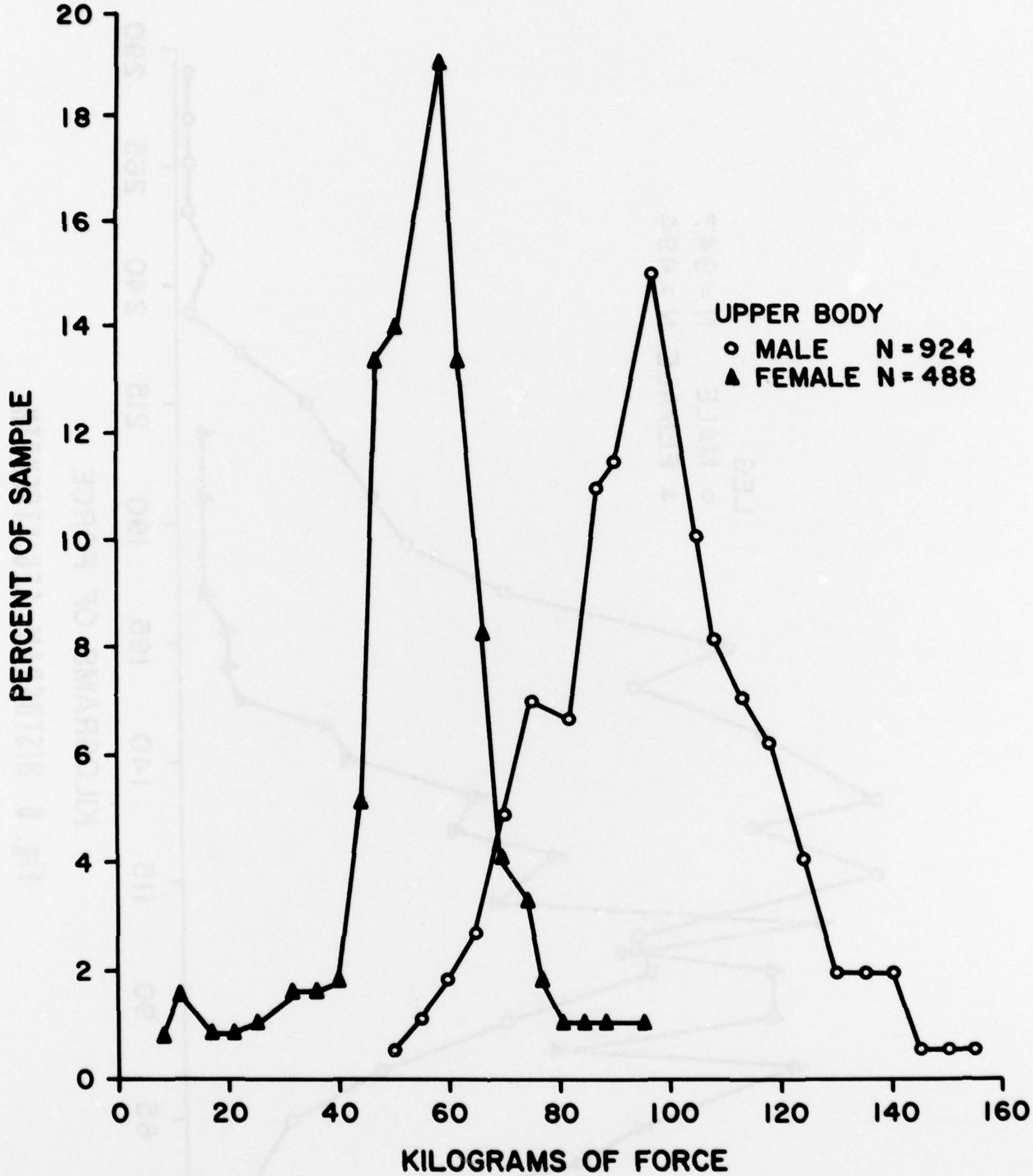

Fig. 7 HISTOGRAM, UPPER BODY STRENGTH

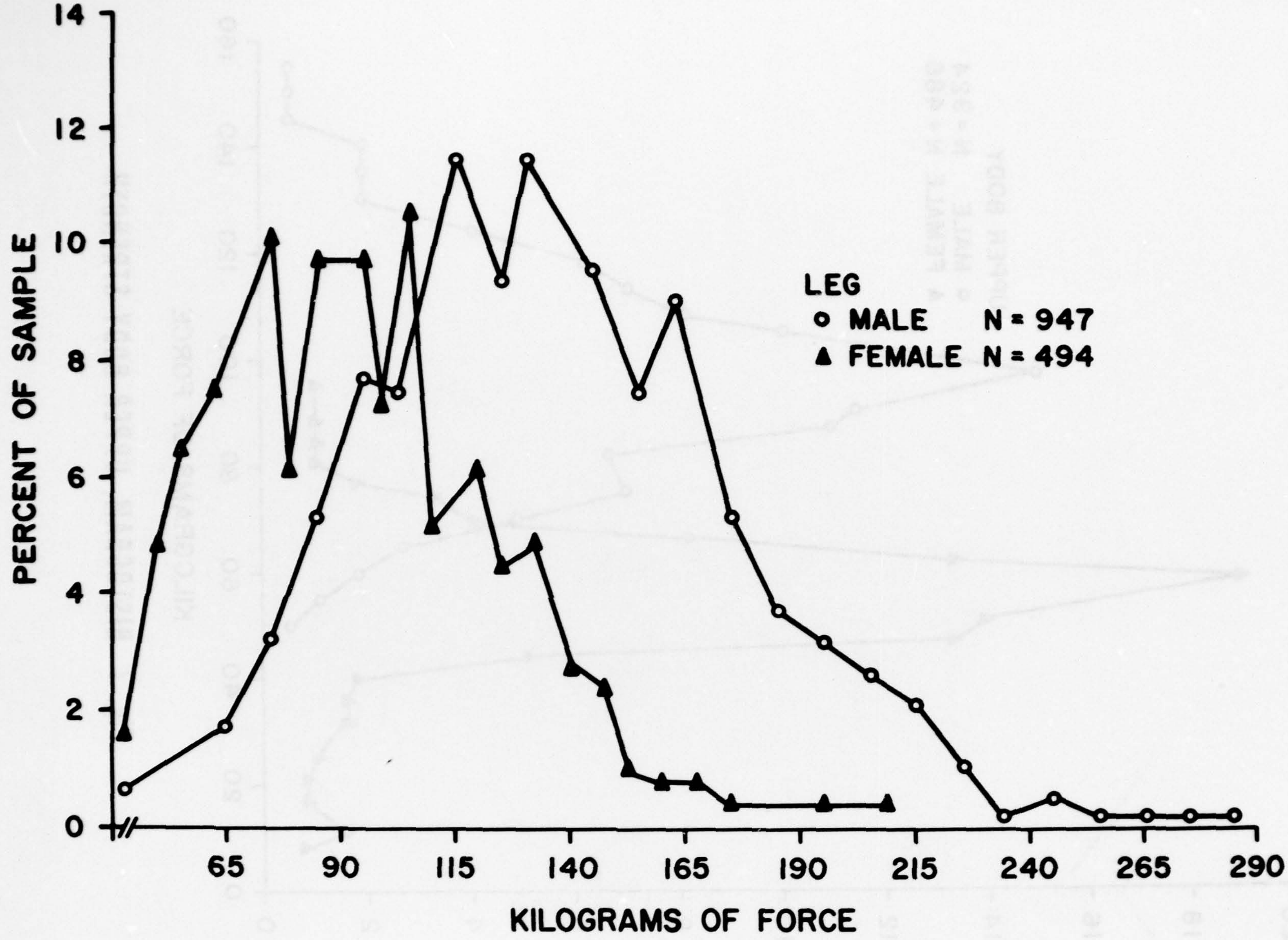

Fig. 8 HISTOGRAM, LEG STRENGTH

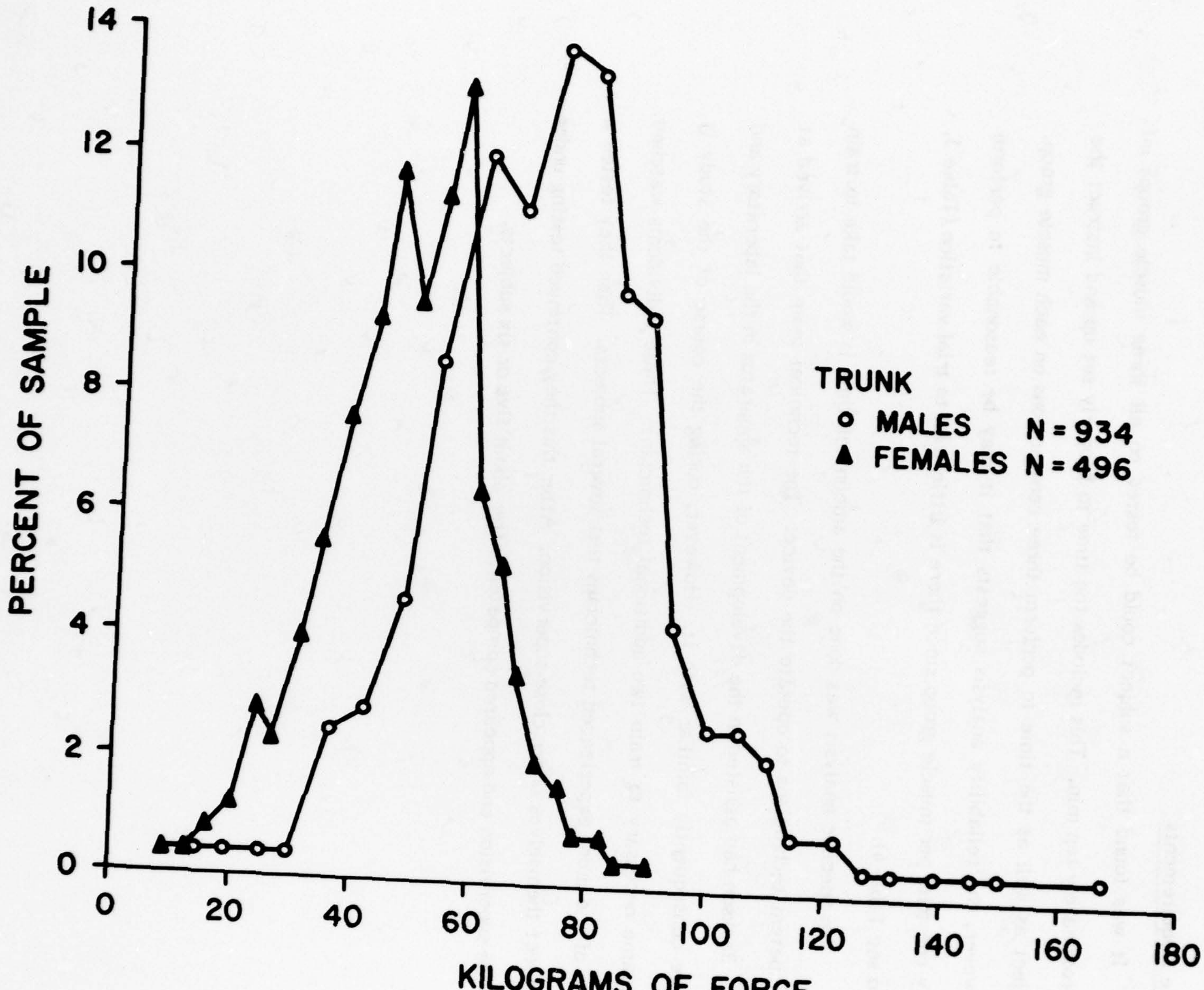

Fig. 9 HISTOGRAM, TRUNK STRENGTH

Time Requirements

It was found that a subject could be tested on all three muscle groups in approximately ten min. This includes the time to properly set up and instruct the subject as well as the time to perform three contractions on each muscle group. However, the reliability analysis suggests that it may be reasonable to perform only one trial per muscle group since there is little trial to trial variation (Table 3, also see Table 4).

No specific analysis was done on the amount of time it would take to train competent technicians to operate the device. The technical team that arrived at Ft. Jackson had assisted in the development of the apparatus in the laboratory and were consequently familiar with it. However, during the course of the study it became necessary to train two additional technicians. These individuals watched one of the more experienced technicians test several subjects. Then they tested a subject themselves under close supervision. After this they continued testing under loose supervision and appeared competent after about five or six subjects.

SUMMARY

The device presented in this report was designed for use in the AFEES. It measures three major muscle groups (upper body, legs and trunk) that appear important for military tasks. The isometric mode of testing was selected and appropriate biomechanical factors were considered. Reliability of the upper body and leg portions appear acceptably high and attempts to improve the reliability of the trunk portion are on-going. Normative data was collected on a sample of basic trainees.

The apparatus is currently being modified to record force measurements via load cell transducers and to display these measurements as digital readouts. This has been found to simplify calibration and may increase the accuracy of the measure. The device is also being validated against common military tasks.

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APPENDIX

Instructions for Static Strength Device

I. GENERAL INSTRUCTIONS - We are interested in measuring the maximal strength of your arms, legs and back. In order to do this, you will exert as much force as possible against various parts of this apparatus. I will explain to you exactly what you will be doing as we get to each of the three stations here.

A. Seating - Sit with your buttocks all the way back in the chair. Place your feet on the bar in front of you with the arch of your feet in the center.

B. Upper Body

1. Grasp the bar with your palms facing you and about shoulder distance apart.

2. You are to pull down on the bar as hard as possible without leaning forward when I give you the command.

3. The bar will not move.

4. I will give you a 1,2,3 pull then I want you to build up to your maximal strength as rapidly as possible and hold it until I tell you to stop. Do not jerk the bar; build up to your maximal strength rapidly and hold it until I say "relax".

5. On this test as with all the tests, you will do three contractions, with a short rest in between, then you will go on to the next station.

C. Legs

1. Grasp the side of the seats using the hand holds.

2. You are to push out on the bar with your legs as hard as possible.

3. You will find that there is a tendency to lift out of the seat as you push out. You can avoid this by pulling yourself down into the seat with the handholds at the same time you push out with your legs.

4. Do not lean forward.

5. The bar will not move.

6. Again,build up to your maximal strength as rapidly as possible without jerking.

7. You will perform three contractions.

D. Trunk

1. Stand facing the apparatus with your toes against the plate and your feet as close together as possible.

2. Place your hands on your thighs.

3. You are to pull back as hard as possible on the strap while pushing forward with your hips on the pad.

4. Do not bend your knees.

5. Again, build up to your maximal strength as rapidly as possible without jerking.

II. CHECKPOINTS FOR TESTER

A. Upper Body

1. Adjust the chain and pulley so that the upper arm is parallel to the floor and the elbow angle is 90°. This angle is formed by the acromion process, lateral epicondyle and ulnar process of the right arm.

2. The subject's hands should be equidistant from center of bar.

3. The seat belt should be tight.

B. Legs

1. The subject must sit with buttocks completely back in seat.

2. Adjust the angle of knee to 90°. This angle formed by the greater trochanter, lateral condyle and lateral malleolus of the right leg.

3. Arch of both feet should be in the center of the bar.

C. Trunk

1. Adjust the breast plate such that the top of the strap is about three inches from the acromion process.

2. The strap should be tight.

3. The subject's hands should be on his thighs.

4. The subject's feet should be together and touching toe plate.

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